OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper 40*

Third Progress Report
for the Period
April 1, 1998 through January 31, 1999

Lesley Tarleton Julian
Bingzhang Lin, Julie M. Daniel and Michael Yekta

Office of Hydrology
U.S. National Weather Service
Silver Spring, Maryland

February 1999

DISCLAIMER

TABLE OF CONTENTS

OHIO RIVER PRECIPITATION FREQUENCY STUDY
Update of *Technical Paper 40*

Third Progress Report
for the Period
April 1, 1998 through January 31, 1999

I. STUDY OVERVIEW

A. Purpose and Scope

The Hydrometeorological Design Studies Center, Office of Hydrology, U.S. National Weather Service is performing a precipitation frequency study to update Technical Paper No. 40, *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* for the Ohio River basin. The study involves the completion of certain specific tasks including collecting and performing quality control of data, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping, and preparing reports and other documentation.

B. Study Area

The study area covers 13 states completely and parts of nine additional bordering states. The Susquehanna River and Delaware River basins are also included in the study area.

Currently, the study area is divided into 16 homogeneous climatic (i.e., defined as extreme precipitation climate) regions. Factors considered in defining the regions include 1) the season (or seasons) of highest precipitation, 2) the type of precipitation (e.g., general storm, convective, tropical storms or hurricanes, or a combination), 3) the climate, 4) the topography (especially as it interacts with the weather systems), and 5) the homogeneity of these factors in a single area. The regions may be re-defined during the course of the study.

The study area is displayed in Figure 1. The core and bordering states and regional boundaries are shown on the figure.

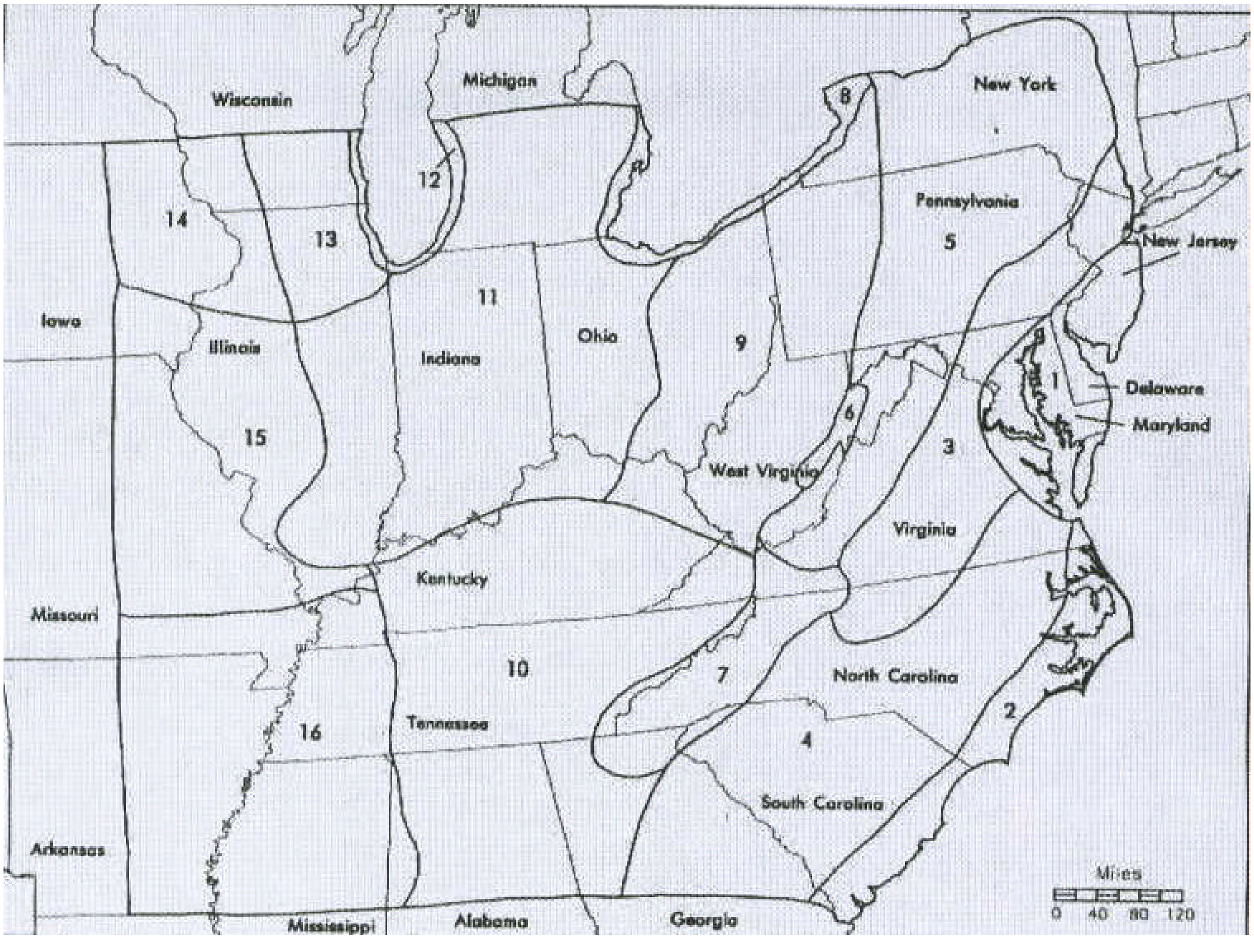

Figure 1. Ohio River study area and preliminary region boundaries.

II. TASK STATUS

The following sections discuss the status of each ongoing task and provide a short technical description of decisions made and task accomplishments, when applicable. Project tasks not discussed are in the planning stages or have yet to get started. Past status reports should also be referenced for additional information.

A. Data Collection and Quality Control

Work has been ongoing in compiling datasets, formatting data and performing quality control on the data. This task is not yet complete. The following sections discuss the status of ongoing or completed activities involving daily, hourly and n-minute datasets.

1. Daily Data

- Daily precipitation data obtained from the National Climatic Data Center (NCDC), the U.S. Army Corps of Engineers (COE) and the U.S. Geological Survey have all been reformatted and are ready for further processing and analyses.

- Some additional hourly data were received from the COE. These data will be used to compute 24-hour totals and then added to the daily dataset.

- All daily data previously hand-entered by the project team have been added to the NCDC daily dataset and quality-controlled.

- Additional data were received from the Midwestern Climate Center Digitization Project and have been merged into the daily dataset.

- All leading and trailing months with missing data have been trimmed out of the data files.

- Daily data hand-entered by the Tennessee Valley Authority have been merged into the daily dataset.

- The software used to create the station list files was modified to compute the percentage of available, valid precipitation data and the percentage of non-accumulated data for each station. These values are written as the two last fields for the station in the station list file. In the example for station *Chattanooga WSO AP* (Tennessee) shown following this paragraph, there are no missing or accumulated data (note the two fields at the end of the data line are both 100).

Example Station List File (Data Recovery and Accumulation Fields)

```
62 TN  CHATTANOOGA WSO AP  40-1656   35.03  85.20  690    1/1928 - 12/1996   PP24   100   100
```

- The software used to compute partial-duration series for daily data was modified to reject stations with less than 20 years (or 240 months) of valid data. Criteria to determine whether a month is valid and counts toward the 20 years are:

  For the 1-day duration dataset, the month is considered invalid if any of the following are true -

  - Each day of the month has no valid data;
  - There are more than 10 days with missing data and the total precipitation in the month is 0.00 inches, or;
  - There are more than 15 days of missing data and the maximum 1-day precipitation in the month is less than 30% of the average 1-day precipitation for that month.

  For the 2 - 60 day duration dataset, a similar set of conditions is applied.

- The software computing partial durations for daily data has been designed to produce the following three types of output files -

  - A **partial series file** for each duration with *N* number of partial duration amounts for each station in descending order (where *N* = the actual number of years for that station). This file is then used as input to the L-moments program (see Section II.B of this report);
  - A **date file** which contains the dates corresponding to the event (The day provided in the file is the day with the highest precipitation within the duration.), and;
  - A **computation file** containing detailed information about the computation of partial durations.

Examples of the partial duration file types are provided in Appendix A.

2. Hourly Data

- All hourly station data from NCDC tapes have been extracted and reformatted.
- All leading and trailing days with missing data have been trimmed from the data files.
- Merging of stations for all states has been completed.

- One-hour annual maximum precipitation values for all states were computed.

- All years with a total of 0.00 inches of precipitation were flagged as missing data years.

- As with the daily data, the software used to compute partial durations for hourly data was modified to reject stations with less than 20 years (or 240 months) of valid data. The criteria to determine whether a month is valid and counts toward the 20 years are:

    - Each hour of the month is invalid;
    - More than 240 hours with missing data and the total precipitation for the month is 0.00 inches, or;
    - More than 360 hours of missing data and maximum 24-hour precipitation in the month is less than 30% of the 24-hour average precipitation for that month.

- The software computing partial durations for 1, 2, 3, 6, 12, 24 and 48 hours has been designed to produce the following three types of output files -

    - A **partial series file** for each duration with *N* number of partial duration amounts for each station in descending order (where *N* = the number of actual data years for that station). This file is then used as input to the L-moments program (see Section II.B of this report);
    - A **date file** which contains the month and year corresponding to the event (The month provided in the file is the month with the highest 1-hour precipitation within the duration.), and;
    - A **computation file** containing detailed information about the computation of partial durations.

Examples of the partial duration file types are provided in Appendix B.

3. N-minute Data

Digital n-minute data for 76 stations were obtained from NCDC in two different datasets. The first dataset contains monthly precipitation maximums for 5-, 10-, 15-, 30-, 45-, 60-, 80-, 120-, 150-, and 180-minute durations and covers the period from 1973 through 1979. The second dataset contains monthly maximum data for the same durations as the first dataset and covers the period from 1983 through 1997. Data for 1980 and 1981 were not available in a digital format but were available in hard copy from NCDC's Local Climatological Data monthly publication. No n-minute data, digital or hard copy, were available for 1982. The two digital datasets were merged into a common format. Hand-entered data for 1980 and 1981 were added by the project team. Software was written to compute annual maximum and partial duration series for 5-, 10-, 15-, 30-, 60-, and 120-minute durations, which will be used as input data to the L-moment program.

Additionally, annual maximum n-minute data (as opposed to the monthly maximum data describe above) for 84 stations were obtained from a previous in-house study. This dataset provides annual maximum data for 5-, 10-, 15-, 30-, 60-, and 120-minute durations. These data start as early as 1898 and end in 1987. Because the digital data from NCDC continues to 1997, a program was written to append annual maximum data from the digital NCDC dataset to the in-house dataset for stations common to both datasets. Software was written to reformat the annual maximum data to make it compatible with the input format needed for the L-moment program. The following is an example of the annual maximum series file for Birmingham, AL (60minute duration for 87 data years).

Example Sixty Minute, Annual Maximum Duration Series

```
      1 60-minute, Annual Maximum
(0601904) 01-0831 ANMAX
 87
  1.32   1.16   1.79   1.27   1.32   1.37   2.23   1.57   1.55   1.67
  1.28   2.01   1.66   2.37   2.09   1.14   2.01   1.20   1.80   1.92
  1.32   1.82   1.13   1.36   1.98   2.25   1.35   1.55   1.61   1.36
  1.75   2.05   1.11   1.52   1.56   2.65   1.32   3.83   2.37   1.23
  1.15   1.23   2.16   2.44   1.47   1.19   2.26   2.46   2.12   1.73
  1.40   1.08   1.85   2.43   1.13   1.46   1.08   1.80   1.30   3.02
  1.32   1.60   1.48   3.18   1.24   1.68   1.35   1.88   1.60   1.56
  1.16   1.08   1.18   2.17   1.30  -9.99  -9.99  -9.99  -9.99  -9.99
 -9.99  -9.99  -9.99   0.70   1.71   1.38   1.46
```

B. Frequency Distribution Fitting Analyses

This task is to evaluate and select the frequency distribution(s) which provides the best fit for the data. Work has been ongoing in the selection of applicable frequency distributions. In addition, an evaluation of the impact of the regionalization was performed. The results from these studies are described in the remainder of this section.

The L-moment analysis technique was used to fit the data and to choose the most applicable distributions. The L-moment technique is also used to analyze the appropriateness of the regionalization of the study area discussed in Section I.

1. Background

In order to accomplish the best-fit and regionalization impact analyses, a hybrid region, Region 11a, consisting of three entire states - Ohio, Indiana and Illinois was created. Table 1 gives a brief overview on the status of the precipitation stations for the daily and hourly data in the region.

Table 1. Status of precipitation stations for Region 11a (daily/hourly).

	Ohio	Indiana	Illinois	Total Region 11a
Number of Stations	218/105	159/74	208/74	585/253
Average data length (years)	61/40	59/42	65/40	62/41
Maximum data length (years)	114/49	101/49	110/50	114 50
Minimum data length (years)	21/20	21/20	21/21	21/20

The best-fit and regionalization studies were performed both for each state individually and as a region consisting of all three states. One-day and 6-hour precipitation data were used in the computations.

2. Best-fit Analysis

Three independent test methods were used to determine which theoretical distribution is the best fit for the three states and Region 11a. The precipitation stations shown in Table 1 were used in this analysis. The three test methods selected were 1) the *real-data-check*, 2) the *4-criteria* and 3) the *xtest*. Table 2 lists the top three best-fit distributions from among the five commonly used hydrometeorological distributions - GEV (Generalized Extreme-Value), LNO (Log-Normal), GLO (Generalized Logistic), GPA (Generalized Pareto) and PE3 (Pearson Type III).

Table 2. Best-fit distributions for 1-day and 6-hour durations for both annual maximum and partial duration for individual states and Region 11a.

Fitting methods	Fitting rank	1-Day								6-Hour							
		Annual Maximum				*Partial Duration*				Annual Maximum				*Partial Duration*			
		IL	IN	OH	Entire Region	*IL*	*IN*	*OH*	*Entire Region*	IL	IN	OH	Entire Region	*IL*	*IN*	*OH*	*Entire Region*
Real data check	Best	GEV	LNO	GEV	GEV	*GPA*	*PE3*	*GPA*	*GPA*	GLO	LNO	GEV	GEV	*GPA*	*PE3*	*GPA*	*GPA*
	2nd	LNO	GEV	LNO	LNO	*LNO*	*GPA*	*PE3*	*PE3*	GEV	GEV	GLO	LNO	*LNO*	*GPA*	*LNO*	*PE3*
	3rd	GLO	PE3	GLO	GLO	*GEV*	*LNO*	*LNO*	*LNO*	LNO	PE3	LNP	GLO	*PE3*	*LNO*	*PE3*	*LNO*
xtest	Best	GEV	GEV	GEV	GEV	*GPA*	*GPA*	*GPA*	*GPA*	GEV	GEV	GEV	GEV	*GPA*	*GPA*	*GPA*	*GPA*
	2nd	LNO	LNO	GLO	LNO	*PE3*	*PE3*	*PE3*	*PE3*	GLO	LNO	GLO	GLO	*PE3*	*PE3*	*PE3*	*PE3*
	3rd	GLO	PE3	LON	GLO	*LNO*	*LNO*	*LNO*	*LNO*	LNO	GLO	LNO	LNO	*LNO*	*LNO*	*LNO*	*LNO*
4 criteria	Best	GEV	GEV	GEV	GEV	*GPA*	*GPA*	*GPA*	*GPA*	GEV	GEV	GEV	GEV	*GPA*	*GPA*	*GPA*	*GPA*
	2nd	LNO	LNO	LNO	LNO	*PE3*	*PE3*	*PE3*	*LNO*	LNO	LNO	LNO	LNO	*PE3*	*PE3*	*PE3*	*PE3*
	3rd	GLO	PE3	GLO	GLO	*LNO*	*LNO*	*LNO*	*PE3*	GLO	GLO	GLO	GLO	*LNO*	*LNO*	*LNO*	*LNO*
Overall Best-fit		**GEV**	**GEV**	**GEV**	**GEV**	***GPA***	***GPA***	***GPA***	***GPA***	**GEV**	**GEV**	**GEV**	**GEV**	***GPA***	***GPA***	***GPA***	***GPA***

As shown in the table, the results of the three test methods are in close agreement for both the daily and hourly precipitation data. Overall, for both the 1-day and the 6-hour durations, the GEV provides the best distribution for the annual maximum sample data while the GPA is the best for the partial duration sample data.

3. Comparison of 1-day Precipitation Frequency Values by Individual State and Region 11a (Plotting Position Parameters: A= 0, B= 0)

A preliminary analysis was performed to compare the 1-day precipitation frequency values for states separately and for the entire region. To reduce the amount of computations needed, different distributions were examined for one station from each of the three states in Region 11a. Regional growth factors applied to the precipitation frequency values were based on data from all stations within a state and all stations within the region.

A station was selected only if it had the same or nearly the same record length for both daily and hourly datasets and similar to the average record length for the state. These requirements ensured that reasonable comparisons between daily and hourly results could be made. The three stations selected were:

- Ohio - Station 33-5894: N= 45 years for daily and N= 40 years for hourly data
- Indiana - Station 12-7069: N= 49 years for both daily and hourly data
- Illinois - Station 11-3262: N= 49 years for both daily and hourly data

Table 3 lists the 1-day precipitation values in inches of 2-, 5-, 10-, 25-, 50- and 100-year frequencies for different distributions. The three best-fit distributions are listed in order for the annual maximum data (*.max) while only the best-fit is listed for the partial duration data (*.pd).

Table 3. Comparison of 1-day precipitation frequency values in inches (plotting position parameters: A=0, B=0).

Station ID	Distri-bution	Region 11a (all three states combined for computations)						Single State (three states treated separately for computations)					
		Return periods (years)						Return periods (years)					
		2	5	10	25	50	100	2	5	10	25	50	100
33-5894 (OH)	**GPA.pd**	2.092	2.611	3.022	3.590	4.040	4.507	2.094	2.596	2.999	3.563	4.017	4.494
	GEV.max	**1.961**	**2.591**	**3.033**	**3.623**	**4.084**	**4.562**	1.965	2.575	3.004	3.578	4.026	4.492
	LNO.max	1.959	2.602	3.045	3.621	4.060	4.509	1.963	2.586	3.016	3.575	4.003	4.440
	GLO.max	1.973	2.550	2.975	3.596	4.136	4.754	1.976	2.536	2.948	3.551	4.076	4.677
12-7069 (IN)	**GPA.pd**	2.154	2.688	3.111	3.695	4.158	4.639	2.164	2.695	3.103	3.651	4.072	4.499
	GEV.max	**2.051**	**2.709**	**3.172**	**3.788**	**4.270**	**4.769**	2.058	2.710	3.162	3.757	4.217	4.689
	LNO.max	2.048	2.721	3.184	3.786	4.245	4.714	2.057	2.720	3.172	3.754	4.195	4.642
	GLO.max	2.063	2.666	3.110	3.760	4.324	4.970	2.070	2.667	3.102	3.732	4.276	4.894
11-3262 (IL)	**GPA.pd**	2.543	3.174	3.673	4.364	4.910	5.478	2.532	3.187	3.708	4.432	5.009	5.612
	GEV.max	**2.367**	**3.127**	**3.661**	**4.373**	**4.929**	**5.506**	2.356	3.145	3.703	4.453	5.042	5.657
	LNO.max	2.365	3.141	3.675	4.370	4.901	5.442	2.353	3.160	3.719	4.451	5.012	5.586
	GLO.max	2.381	3.078	3.591	4.340	4.992	5.738	2.371	3.094	3.630	4.417	5.104	5.894

Table 3 shows that the daily precipitation frequency values for Region 11a are systematically higher than Ohio (based on station 33-5894) and Indiana (based on station 12-7069) for return periods greater than two years; while the precipitation frequency values for Region 11a are lower than Illinois (based on station 11-3262). This can be expected, since, the regionalization may smooth the differences in data between adjacent states.

Table 3 also shows that the daily GEV.max (GEV of annual maximum data) is generally higher than the daily GPA.pd (GPA of partial duration data) for the 50- and 100-year return periods for all three stations. The exception is the 100-year return period for Ohio (based on station 33-5894) where the GEV.max nearly equals the GPA.pd.

4. Comparison of 6-hour Precipitation Frequency Values by Individual State and Region 11a (Plotting Position Parameters: A= 0, B= 0)

A comparison analysis similar to that performed for the 1-day precipitation frequency values was performed for the 6-hour values. The same three stations used in the 1-day analysis in Table 3 were used as the basis in this analysis. Table 4 presents the 6-hour precipitation frequency values in inches of 2-, 5-, 10-, 25-, 50- and 100-year return periods for different distributions. The three best-fit distributions are listed in order for the annual maximum data while only the best-fit is listed for the partial duration data.

Table 4. Comparison of 6-hour precipitation frequency values in inches (plotting position parameters: A=0, B=0).

Station ID	Distri-bution	Region 11a (all three states combined for computations)						Single State (three states treated separately for computations)					
		Return periods (years)						Return periods (years)					
		2	5	10	25	50	100	2	5	10	25	50	100
33-5894 (OH)	GPA.pd	1.854	2.348	2.739	3.278	3.704	4.147	1.858	2.344	2.727	3.254	3.670	4.100
	GEV.max	1.676	2.270	2.682	3.226	3.647	4.080	1.680	2.268	2.674	3.207	3.617	4.037
	LNO.max	1.675	2.279	2.691	3.223	3.627	4.036	1.678	2.276	2.682	3.203	3.599	3.996
	GLO.max	1.687	2.230	2.627	3.203	3.700	4.266	1.690	2.228	2.619	3.184	3.671	4.223
12-7069 (IN)	**GPA.pd**	1.917	2.428	2.832	3.390	3.830	4.288	1.924	2.421	2.812	3.348	3.769	4.204
	GEV.max	1.668	2.259	2.669	3.211	3.630	4.061	1.674	2.255	2.655	3.177	3.578	3.987
	LNO.max	1.667	2.268	2.678	3.207	3.609	4.017	1.673	2.263	2.662	3.173	3.559	3.948
	GLO.max	1.679	2.220	2.614	3.187	3.682	4.245	1.685	2.216	2.601	3.156	3.632	4.172
11-3262 (IL)	**GPA.pd**	2.205	2.793	3.257	3.899	4.405	4.931	2.191	2.808	3.301	3.988	4.536	5.110
	GEV.max	2.006	2.717	3.210	3.862	4.366	4.884	1.992	2.724	3.242	3.938	4.486	5.058
	LNO.max	2.005	2.728	3.221	3.858	4.341	4.831	1.989	2.738	3.257	3.937	4.458	4.991
	GLO.max	2.019	2.670	3.145	3.834	4.429	5.106	2.005	2.677	3.174	3.905	4.544	5.277

Like the 1-day data analysis (Table 3), Table 4 shows that the 6-hour precipitation frequency values for Region 11a are systematically higher than Ohio (based on station 33-5894) and Indiana (based on station 12-7069) for return periods greater than two years; while the precipitation frequency values for Region 11a are lower than Illinois (based on station 11-3262) . In contrast to the 1-day data analysis, the 6-hour GEV.max is lower than the GPA.pd for all frequencies for all three stations.

5. Impact of Plotting Position Parameters on Precipitation Frequency Values

To investigate the impact of the plotting position formula in combination with a certain distribution on precipitation frequency values, two different sets of plotting position parameter sets were compared. The first set is A= 0 and B= 0 and the second is A= -0.35 and B= 0 using a general plotting position formula of $P_J = (J+A)/(N+B)$ where J is the Jth smallest value in the data series and the N is the dataset size. The same three stations used in the analysis for Table 3 were used in this analysis.

According to the literature, the optimal combination is A= -0.35 and B= 0 since this provides good results for both the GPA and GEV distributions.

Tables 5 and 6 show the results for the analysis for the combination of A= -0.35 and B= 0. The precipitation frequency values for LNO.max and GLO.max were omitted in the tables since they are not as important in this evaluation.

Table 5. Comparison of 1-day precipitation frequency values in inches (plotting position parameters: A=-0.35, B=0).

Station ID	Distri-bution	Region 11a (all three states combined for computations)						Single State (three states treated separately for computations)					
		Return periods (years)						Return periods (years)					
		2	5	10	25	50	100	2	5	10	25	50	100
33-5894 (OH)	**GPA.pd**	2.093	2.629	3.044	3.608	4.044	4.490	2.095	2.614	3.022	3.582	4.021	4.475
	GEV.max	1.959	2.595	3.043	3.641	4.109	4.596	1.963	2.580	3.014	3.596	4.052	4.525
12-7069 (IN)	**GPA.pd**	2.154	2.706	3.134	3.713	4.163	4.622	2.164	2.713	3.126	3.670	4.080	4.488
	GEV.max	2.048	2.713	3.181	3.807	4.296	4.805	2.055	2.714	3.173	3.778	4.247	4.729
11-3262 (IL)	**GPA.pd**	2.544	3.195	3.701	4.385	4.916	5.458	2.533	3.207	3.733	4.452	5.013	5.590
	GEV.max	2.364	3.132	3.672	4.394	4.959	5.547	2.354	3.149	3.713	4.472	5.070	5.694

Table 6 Comparison of 6-hour precipitation frequency values in inches (plotting position parameters: A=-0.35, B=0).

Station ID	Distri-bution	Region 11a (all three states combined for computations)						Single State (three states treated separately for computations)					
		Return periods (years)						Return periods (years)					
		2	5	10	25	50	100	2	5	10	25	50	100
33-5894 (OH)	**GPA.pd**	1.855	2.373	2.770	3.300	3.706	4.116	1.859	2.369	2.758	3.277	3.673	4.071
	GEV.max	1.673	2.273	2.692	3.248	3.679	4.124	1.676	2.271	2.684	3.229	3.650	4.083
12-7069 (IN)	**GPA.pd**	1.918	2.454	2.864	3.412	3.832	4.256	1.925	2.446	2.843	3.370	3.771	4.174
	GEV.max	1.665	2.262	2.679	3.232	3.661	4.104	1.671	2.259	2.665	3.198	3.609	4.029
11-3262 (IL)	**GPA.pd**	2.206	2.822	3.294	3.925	4.408	4.895	2.192	2.837	3.337	4.013	4.537	5.071
	GEV.max	2.002	2.721	3.223	3.887	4.404	4.937	1.988	2.728	3.254	3.962	4.521	5.106

Comparisons of Table 5 (1-day; A=-0.35, B=0.0) with Table 3 (1-day; A=0.0, B=0.0) and Table 6 (6-hour; A=-0.35, B=0.0) with Table 4 (6-hour; A=0.0, B=0.0) show when using the A= -0.35 and B= 0 parameter set for the GEV.max distribution, the precipitation frequency value values are greater than when A= 0 and B= 0 are used. The opposite results are shown for the GPA.pd distribution, where the precipitation frequency value values are lower for the A= -0.35 and B= 0 parameter set.

6. Impact of Regionalization on Precipitation Frequency Values

To investigate the impact of regionalization on precipitation frequency values for a station, the L-moments computation was performed on each state separately and as an overall region. Using the data shown in Tables 3 - 6, the precipitation frequency values for Region 11a are greater than the precipitation frequency values for Ohio and Indiana but lower than the precipitation values for Illinois .

7. Summary

- The results seem reasonable and no major inconsistencies are apparent in the L-moment computations.

- For the test region, the best-fit distributions are GPA (Generalized Pareto) for partial duration data and GEV (Generalized extreme-value) for annual maximum data, respectively, no matter how the data for the three stations were treated - as a single state or as a region as a whole. This conclusion is true for both the 1-day and 6-hour durations.

- When using the plotting position parameter set of A= 0 and B= 0, the 1-day precipitation frequency values of GEV.max (GEV of annual maximum data) are higher than that of GPA.pd (GPA of partial duration data) for all three stations. By contrast, the 6-hour precipitation frequency values of GEV.max are lower than that of GPA.pd for all three stations. This may be attributed to the different nature of the hourly data versus daily data. For partial duration data, there are more chances to collect samples with relatively higher values for hourly data than for daily data.

- The plotting position parameters have shown some impact on precipitation frequency values in past studies, but not much of an impact in the Region 11a evaluation for the A= 0 and B= 0 and A= -0.35 and B= 0 parameter sets. The GEV.max using A= -0.35 and B= 0 is systematically higher than the GEV.max using A= 0 and B= 0 for both the 1-day and 6-hour durations. While the GPA.pd using A= -0.35 and B= 0 is systematically lower than the GPA.pd using A= 0 and B= 0 for both the 1-day and 6-hour durations. The combination of A= -0.35 and B= 0 is the optimal parameter set for the GEV and the GPA distributions using the plotting position formula of $P_J = (J+A)/(N+B)$.

- The regionalization does have impact on precipitation frequency values with respect to a state. For return periods greater than two years, the precipitation frequency values for Region 11a are greater than the precipitation frequency values for Ohio (based on station 33-5894) and Indiana (based on station 12-7069) ; while the precipitation frequency values for Region 11a are lower than Illinois (based on station 11-3262) . This is true for both the 1-day and 6-hour data. This difference in the comparison of the states separately implies that the precipitation in Illinois may be above the regional average while the precipitation in Ohio and Indiana may be below the regional average. The departures from the average shown in this analysis were not significant.

Appendix A

Example Partial Duration Output File Types
for
Daily Data

Provided below are sample output files from the daily data partial duration computation software (refer to Section II.A). These sample files are all for station *Chattanooga WSO AP*.

Seven Day Partial Duration Series for 69 Data Years

```
  1   7-day, Partial Duration, TN       1.00     1.00     1.00     1.00    1.00     1.00     1.00     1.00     1.00     1.00
(071928) 40-1656 PD
  69
  10.02    8.91     8.83     8.73     8.43     8.20     7.87     7.81     7.57     7.56
   7.55    7.50     7.50     7.41     7.39     7.33     7.32     7.25     7.20     7.09
   7.07    6.99     6.97     6.96     6.93     6.72     6.68     6.67     6.63     6.44
   6.42    6.41     6.37     6.32     6.31     6.19     6.13     6.12     6.05     6.02
   5.96    5.95     5.94     5.93     5.93     5.89     5.71     5.70     5.69     5.60
   5.51    5.50     5.45     5.44     5.39     5.36     5.33     5.27     5.18     5.18
   5.17    5.13     5.10     5.09     5.08     5.06     5.06     5.04     5.04
40-1656     35.03000000    -85.20000000     690
```

Date File Corresponding to the Partial Duration Series

```
00   1   7-day, Partial Duration, tn
(071928) 40-1656 PD
  69
12/17/1961   03/16/1973   03/20/1980   07/20/1979   09/14/1957   01/19/1947   01/07/1946   03/27/1994   11/13/1929   09/29/1989
02/23/1962   09/23/1975   02/12/1948   02/19/1991   09/07/1977   12/28/1942   01/15/1954   07/04/1941   01/31/1957   03/29/1977
07/11/1994   07/06/1967   05/02/1964   07/14/1949   07/28/1972   03/12/1963   03/26/1965   01/02/1936   02/22/1961   07/03/1989
11/17/1957   09/07/1950   11/27/1983   03/02/1934   06/15/1949   02/02/1956   12/22/1990    08/16/1935  02/02/1969   06/20/1989
11/24/1986   12/20/1951   10/16/1932   11/28/1948   03/24/1934   12/10/1932   02/15/1990   07/25/1971   03/28/1951   09/13/1966
12/01/1982   12/25/1973   10/05/1995   01/04/1948   04/07/1964   07/19/1933   02/12/1945   04/01/1936   01/03/1981   03/12/1950
09/01/1928   03/14/1929   07/20/1963   05/02/1984   12/03/1931   02/15/1995   10/17/1949   01/19/1988   01/21/1959
```

The day provided in the file is the day with the highest precipitation within the duration.

Computation File - 1973 Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
40-1656	03/1973	8.91	(7)	75	03/16	4.68	6	70	03/11	0	0.00	0	0	0
40-1656	12/1973	5.50	(7)	359	12/25	2.01	1	359	12/25	0	0.00	0	0	0
40-1656	11/1973	4.55	(7)	331	11/27	2.85	7	325	11/21	0	0.00	0	0	0
40-1656	09/1973	4.23	(7)	256	09/13	3.59	1	256	09/13	0	0.00	0	0	0
40-1656	05/1973	3.91	(7)	147	05/27	2.23	5	143	05/23	0	0.00	0	0	0
40-1656	07/1973	3.49	(7)	207	07/26	1.99	4	204	07/23	0	0.00	0	0	0

Computation File Key:

The top six seven-day partial duration computations are shown. The fields from left to right are: (1) station ID, (2) month and day when duration began, (3) total precipitation for the duration, (4) duration being computed, (5) Julian day on which the maximum precipitation in the duration occurred, (6) month and day when the maximum precipitation within the duration occurred, (7) amount of maximum precipitation within the duration, (8) offset of the day within the duration on which maximum precipitation occurred, (9) Julian day pointing to the start of the duration, (10) calendar month and day of the beginning of the duration, (11) number of accumulated days within the duration, (12) total accumulated precipitation within the duration, (13) number of missing days within the duration, (14) total number of accumulated days within the year and (15) total number of missing days within the year.

Appendix B

Example Partial Duration Output File Types
for
Hourly Data

Provided below are sample output files from the hourly data partial duration computation software (refer to Section II.A). These sample files are all for station *Chattanooga WSO AP*.

Twenty-four Hour Partial Duration Series for 49 Data Years

```
1 24-hour, Partial Duration, TN      1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
(241948)    40-1656   PD
  49
   6.62     6.53     6.19     5.77     5.75     5.40     4.85     4.85     4.66     4.63
   4.56     4.40     4.39     4.35     4.32     4.27     4.20     4.09     4.04     3.90
   3.87     3.87     3.85     3.81     3.74     3.72     3.72     3.66     3.61     3.60
   3.60     3.57     3.56     3.55     3.52     3.47     3.47     3.46     3.43     3.43
   3.38     3.38     3.38     3.38     3.38     3.36     3.32     3.29     3.25
40-1656    35.03000000    -85.20000000   690
```

Date File Corresponding to the Partial Duration Series

```
    00   1  24-hour, Partial Duration, TN
(241948) 40-1656 PD
  49
  09/1977   03/1973   03/1994   07/1979   03/1980   03/1963   12/1961   06/1949   03/1951   07/1949
  11/1948   01/1949   02/1995   09/1957   09/1979   02/1990   10/1995   03/1964   10/1986   01/1959
  01/1982   12/1973   09/1975   03/1990   02/1962   06/1994   12/1990   09/1950   07/1994   09/1973
  12/1969   01/1988   03/1950   03/1961   10/1977   01/1987   05/1979   05/1964   03/1965   01/1957
  12/1982   11/1979   03/1977   03/1975   03/1960   04/1983   02/1955   03/1952   11/1983
```

The month provided in the file is the month with the highest 1-hour precipitation within the duration.

Computation File - March 1973 Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
40-1656	03/1973	1.17	(1)	1783	03/16:07	1.17	1	1783	03/16:07	0	0.00	0	0	0
40-1656	03/1973	1.37	(2)	1783	03/16:07	1.17	1	1783	03/16:07	0	0.00	0	0	0
40-1656	03/1973	1.58	(3)	1790	03/16:14	0.70	2	1789	03/16:13	0	0.00	0	0	0
40-1656	03/1973	2.07	(6)	1790	03/16:14	0.70	5	1786	03/16:10	0	0.00	0	0	0
40-1656	03/1973	3.85	(12)	1783	03/16:07	1.17	12	1772	03/15:20	0	0.00	0	0	0
40-1656	03/1973	6.53	(24)	1783	03/16:07	1.17	16	1768	03/15:16	0	0.00	0	0	0
40-1656	03/1973	7.50	(48)	1783	03/16:07	1.17	23	1761	03/15:09	0	0.00	0	0	0

Computation File Key:

The partial duration computations for all durations are shown. The fields from left to right are: (1) station ID, (2) month and year of duration, (3) total precipitation for the duration, (4) duration being computed, (5) number of hours from the beginning of the year to the hour of the highest precipitation within the duration, (6) month, day and hour of the maximum precipitation within the duration, (7) amount of the maximum 1-hour precipitation within the duration, (8) offset of the maximum 1-hour precipitation from the beginning of the duration, (9) number of hours from the beginning of the year to the starting hour of the duration, (10) month, day and hour of the starting hour of the duration, (11) number of accumulated hours within the duration, (12) total accumulated precipitation within the duration, (13) number of missing days within the duration, (14) total number of accumulated hours within the month and (15) total number of missing hours within the month.